GEOLOGICAL REPORT.

By reference to the report of my Assistant, W. W. Borden, it will be seen that from six to ten bands of manganiferous iron-stone have been traced over a very large area in the counties of Clarke and Floyd, occupying a geological position in the gray and greenish shales immediately over the "New Albany Black slate." These ore-bands are found also in Scott and Jennings counties but the extent of territory which they occupy, in the latter counties, remains to be determined by the survey, hereafter to be made.

These ore-bands are enclosed in twenty to twenty-five feet of soft shale and are from two to three feet apart and are from two and a half to ten inches thick. The readiness with which these shales decompose, under the influence of drainage water and atmospheric agencies, has given rise to numerous cone shaped hills commonly called "Knobs" and from this circumstance, also, geologists have given to the rock strata of which they are composed, the name of "Knob Shales" "Knob Sandstone," Limestone etc., so that we may, with like propriety, designate the ore as knob iron ore.

A black, bituminous shale, similar to that underlying this ore is found in Ohio occupying a similar position with reference to the under and overlying rocks, and Dr. Newberry, State Geologist of Ohio, has referred it to the Genessee epoch, but not feeling quite sure as to the accuracy of the conclusion to which this able geologist and paleontologist has arrived, I have thought best to speak of it, in this State, as the New Albany Black Slate.

Near the city of New Albany Dr. Clapp bored through this bed of bituminous slate and found it to be one hundred and ten feet thick. It is being constantly mistaken for the bituminous shale which is often found associated with stone coal and it is a difficult matter, in all instances, to convince the people, living within the vicinity of its outcrop, that it will not turn to coal if followed to a distance in the hills. It contains from ten to twenty per cent of volatile matter and there are found in the deposit in places, thin bands of coal from a half to one inch thick. Dr. Newberry thinks that these shales derived their bitumen from sea weeds, and calls attention to the fact of finding in them vast quantities of fucoidal impressions. So far we have only succeeded in finding in the New Albany black slate a few small Lingula and Decina. In Clarke county there is resting immediately on the top of the black slate, about four inches of hard, greenish, mottled limestone and this is succeeded by the gray argillaceous shales with bands of iron stone alluded to above. There are also found resting on the black slate large trunks and limbs of coniferous trees, the vegetable matter having been replaced by silica in the form of black flint. Specimens of this fossil wood have been placed in the hands of the eminent fossil botanist Prof. Leo Lesquereux, of Columbus, Ohio, for determination and they will be figured and described in some of the forthcoming volumes. A portion of one of these petrified trees, fifteen feet long and two and a half feet wide has been placed in the Indiana Exposition building. Specimens of fossil wood are also found at the same horizon in the black slate at Delphi, Carroll county, Indiana.

Owing to the extensive washes which have cut through the shales the iron-stone is exposed in a great many places throughout the Knob region, and it may be mined or collected, from the ravines already weathered out, at a small cost. Samples from nine distinct bands have been tested for iron, and a complete analysis was made of the bottom and middle bands with the following result:

Analysis of iron-stone from near Henryville, Clarke county, Indiana, (No. 10) bottom band, two and a half inches thick; gray, streaked with greenish lines; outside covered with oxide of iron, which was excluded from that analysed:

Silicic acid	7.300
Per-oxide of iron	2.128
Prot-oxide of iron	34.700
Prot-oxide of manganese	8.940
Alumina	1.100
Lime	5.824
Magnesia	3.027
Sulphur	.254
Phosphorus	.321
Carbonic acid	29.500
Combined water and loss	6.906
	100.000

Metallic iron, 28.48

Analysis of iron-stone from Stewart's farm, near Henryville, Clarke county, Indiana, middle band or 5th from the bottom; four and a half inches thick; of a bluish gray color with an outside coating of red oxide of iron from one-eighth to one-quarter of an inch thick. The latter was excluded from the portion analysed.

Water, @ 212°F	.500
Combined water and organic matter	4.575
Silicic acid	9.300
Per-oxide of iron	2.042
Prot-oxide of iron	35.600
Prot-oxide of manganese	6.628
Alumina	3.600
Lime	7.168
Magnesia	4.612
Sulphur	.274
Phosphorus	.340
Carbonic acid	24.925
Loss and undetermined	.436
	100.000

Metallic iron, 29.12.

In addition to the two very complete results of analyses of this ore, given above, seven other samples, from as many different bands, were tested for iron with the following results, the numbers give the order of succession, No. 1 being the top layer or band, and No. 10 the lowest:

Band No. 1 gave 26.41 per cent. metallic iron.
Band No. 2 gave 26.66 per cent. metallic iron.
Band No. 3 gave 30.51 per cent. metallic iron.
Band No. 4 gave 28.20 per cent. metallic iron.
Band No. 5 gave 29.12 per cent. metallic iron.
Band No. 6 gave 29.74 per cent. metallic iron.
Band No. 7 gave 29.23 per cent. metallic iron.
Band No. 8 gave 27.17 per cent. metallic iron.
Band No. 10 gave 28.48 per cent. metallic iron.

From this it will be seen that the raw ore contains from 26.41 to 30.51 per cent. of iron, and, from the complete analyses of the bottom and middle band, from 5.124 to 6.928 per cent. of the metal manganese.

This class of ores should always be roasted before they are thrown into the blast furnace in order to expel the hygroscopic and combined water and gases. The "Knob ore" will loose about one third of its weight by roasting and the percentage of iron and manganese will be correspondingly greater in the calcined ore so that we have in one hundred parts:

Iron	39.81 to 47.48
Manganese	7.72 to 10.44
Silica	11.00 to 14.02

The average per cent of combined iron and manganese in the calcined ore is 52.72 per cent, consequently two tons of such ore will make a ton of pig iron. The great value which attaches to these ores is mainly due to the large per cent of manganese which they contain, and if properly treated in the smelting furnace they will yield a highly manganiferous pig iron, if not a true spiegeleisen, which metal is found to be indispensable in the manufacture of Bessemer or pneumatic steel.

It will be seen, by reference to the preceding articles, by Hugh Hartmann, on the manufacture of Spiegeleisen in Rhenish Prussia, that the peculiarity of this valuable metal consists in its crystalline structure, due to the manganese which it contains and to a special treatment which it undergoes by adjusting the heat of the furnace and prolonging the time of its cooling after it enters the moulds. The value of a speigeleisen is dependent upon the quantity of manganese which it contains. From 7.5 to 10.0 per cent is of very fair quality.

This per cent of manganese is fully within the capabilities of the Knob ore.

ON THE USE OF RAW COAL IN THE BLAST FURNACE.

Since there has been, in my opinion, a general misunderstanding with regard to the coking properties of the Indiana Block-coal, and of its behavior in the blast furnace, I will add here the conclusions to which I have arrived from investigating this subject, all-important to the manufacturing industries of Indiana. There is a remarkable difference between the caking coal and the non-caking or block coal, both in regard to their physical structure and in the manner of their burning. The latter has a laminated structure, burns without melting and under ordinary treatment makes a soft, poor coke. Whereas the former coal when ignited becomes soft and runs into a mass and ordinarily will make a good, strong coke. Between the extremes of these two well marked varieties of bituminous coal there are many grades of differences and they blend so closely into each other, that it is only as we approach the ends of the chain that a decision can be made without a crucial test as to which variety the specimen under examination belongs. By the ultimate analyses we find no greater variation in the per cent of the contained elementary constituents than is to be found in the different specimens of the same variety of coal. As a means of classification and detection, then, we must look to their physical structure and to their behavior when burning or subjected to the process of conversion into coke. In the laboratory the usual mode of testing the coking properties of a coal is to determine its proximate constituents. This is usually accomplished by drying a weighed portion of the coal, in a hot air bath, for thirty or forty minutes, at a temperature of 212°F.; the loss of weight gives the per cent of hygroscopic water; the residue is burnt and the per cent of ash is found by weighing the incombustible earthy matter. Another portion is placed in a covered platinum crucible and heated to a bright red heat over the gas flame to expel the volatile matter, the loss gives the per cent of gas plus the water determined by the first experiment, and the weight of the charred mass represents the per cent of coke. The per cent of fixed carbon is found by deducting the ash from the coke.

Analysed in the above manner there is a marked difference in the behavior of the two varieties of coal. The particles of the caking coal are fused by the heat applied to the crucible and run into a hard amorpous mass more on less porous and of a steel gray color. On the other hand the block coal does not change form at all, the charred pieces have not melted or fused together and the finer particles may be poured out of the crucible like so much sand.

In order to test the effect of pressure on the quality of the coke, ten grammes of coal, in coarse powder, were coked in a small cast-iron retort with a quarter inch discharge pipe leading from the top into a strong two necked Woulfe's bottle which served as a tar well, from this the gas was carried through a washing bottle and then discharged at the bottom of a tall glass cylinder capable of holding a column of mercury twelve inches in hight without danger of its being thrown out at the top by the force of the escaping gas.

The tabulated results, are given below, of a number of coals charred in the usual way adopted by chemists, in making the proximate analysis of coal, and in the iron retort arranged as above first without pressure and then with pressure formed by adding mercury to the graduated cylinder. The greatest pressure attained was that from a column of mercury twelve inches high or little more than a third of an atmosphere. The crucible was heated to an almost white heat by the uniform flame of a three-jet Bunsen gas burner. The gas which supplied the flame issued under a pressure of one and a half inches of water. The analyses were made, under my direction, by my Assistant Dr. G. M. Levette, whose skill and attention to the work gives assurance of its accuracy.

The Pittsburg coal, tested for coke, was from Stone's mine, and I regret being unable, at the time, to procure a specimen of Connellsville coal, so celebrated for the excellence of its coke ; but since the object of the experiments were to prove the effect of pressure in increasing the density and per cent of coke, it matters but little as to the particular coals used.

The weight of coke obtained when the coal is charred in the iron retort varies according to the character of the specimens treated; with some the gain is but little more than we find by the proximate analyses as usually made in a platinum crucible, while in others, the Sullivan county and Pittsburg coals, the increase of coke is nearly ten per cent, as may be seen by the subjoined table:

COALS COKED UNDER DIFFERENT DEGREES OF PRESSURE.

NAME OF MINE OR OWNER.	Platinum crucible. Proximate analysis.	Iron retort. No mercury.	Iron retort. 3 inches mercury.	Iron retort 6 inches mercury.	Iron retort. 12 inches mercury.
No. 1. H. K. Wilson, Sullivan, Co., Ind.	52.40	59.10	62.00	62.80	59.40
2. Simonson's, Knox Co., Ind	52.50	54.35	54.00	54.30	56.50
3. Shepard & Haslett's, Knox Co. Ind	55.50	56.10	56.40	57.95	56.15
4. Woodruff & Fletcher, Clay Co. Ind	57.50	58.85	60.40	58.50	59.25
5. Barnett's, Clay Co., Ind............	58.50	62.20	61.75	62.60	63.40
6. Stone's, Pittsburg, Pa................	57.90	65.05	65.00	65.10	66.10

H. K. Wilson's coal (No. 1) was tested with other degrees of pressure not enumerated in the above table; one-half inch of mercury, 62.10 per cent of coke; one inch mercury, 61.50 coke; two inches mercury, 60.50 coke; five inches mercury, 61.80 coke; amd with one inch of sand resting directly on the powdered coal in the retort, no other pressure, gave a close grained compact coke, but the percentage could not be accurately determined on account of numerous grains of sand which adhered to the coke.

Nos. 1, 2, 3 and 6, of the table, are caking coals, No.'s 4 and 5 are non-coking or block coals.

The coke from No. 1 made in the retort, without pressure, was moderately firm, close textured, of grayish black color and without lustre; with a pressure exerted by a column of water four inches high (not given in the table) the coke was not increased in weight, but appeared more compact and presented a radiated, crystalline structure, the the rays run from a small central core to the circumference. This peculiar structure was lost when the pressure was increased. Up to a six inch pressure of mercury there was a gain of 3.7 per cent of coke which was very dense and strong. At 12 inches of pressure the per cent of coke was scarcely more than that obtained without pressure and it gave signs of puffing. From this it will be seen that 6 inches of mercury gives the maximum per cent of coke and that beyond this the heat is sufficient to liquify the fixed carbon and expand its particles so as to make a puffed, porous cake. With a half inch of mercury pressure, after the gas had ceased to come over and the washing flask was detached, the pent-up gas would escape from the retort with so much force as to make a loud whistling noise in rushing through the open neck of the Woulfe bottle; the greater the pressure the louder and more prolonged the noise. There was little difference in the time occupied in coking with or without pressure. The average time was forty-five minutes.

Instead of the powdered coal, some pieces, a little larger than a pea, were coked under 6 and 12 inches pressure and they were found unchanged in shape except that the edges were slightly fused and they were cemented together like a pop corn ball. The color and appearance of the pieces resembled anthracite coal far more than coke. Under 12 inches pressure the pieces were slightly swollen, but in color and structure otherwise presented the same appearance as the former.

The effect of pressure on the Pittsburg coal, No. 6, was quite different and equally as remarkable.

The weight of the coke continued to increase up to a pressure of 12 inches where it gained 8.2 per cent over the result in the 1st column, but it was puffed up until the shape resembled a hen's egg and contained a large cavity in the centre of the mass. The fracture presented also a cellular structure like a sponge. Without any pressure this coal gave a moderately dense coke but continued to puff up with every inch of pressure added.

The two caking coals from Knox county, No.'s 2 and 3, gave a cellular coke without pressure and the cells, were only slightly enlarged by twelve inches of pressure, and the weight of the coke in No. 2. at twelve inches was increased by 4 per cent, and that of No. 3 by only 0.65 per cent, while under six inches pressure the increase was 2.45 per cent.

Though these coals do not puff up, under pressure, as much as the Pittsburg coal; the result clearly points out that all three belong to a class of coals that will not make a good coke under pressure, but that the coking oven, like the retorts at the gas works, should be subjected to a process of exhaustion. The coke made from Pittsburg coal in the gas retorts is very close and strong.

No. 4. Woodruff & Fletcher's block coal, Clay county, coked without pressure, gave a coke that possessed but little cohesion; as the pressure increased the coke was more compact, and under twelve inches pressure it was strong and good; the color, like that of No. 1, resembled anthracite rather than coke; the greatest increase was produced by pressure of twelve inches and only amounted to 1.75 per cent.

Barnett's coal, No. 5. This is one of the driest burning of the block coals and the particles were but slightly coherent even under a pressure of twelve inches, the increase in weight, at this pressure, amounted to 4.9 per cent.

The greatest pressure exerted on the block coals did not cause the carbon to become liquid as in the caking coals and the particles were simply cemented together by fusing on the surface. Lumps, when coked under pressure, do not therefore swell, but rather become more dense and homogenous with an increase of heat.

Though the above experiments are not as complete, in many respects, as they should be, I look upon this mode of testing coals as destined to furnish important information with reference to their coking properties and to their behavior in the blast furnace. It appears that in order to make a homogeneous good coke the fixed carbon of the coal must be of a kind that will melt at the lowest possible temperature, for if the process of coking produces the least pressure on the volatile hydrocarbons, whereby there is an increase of heat, such pressure causes so complete a liquifaction and expansion of the fixed carbon that the coke is left cellular instead of being compact. If such a coal is coked by covering it with an inch of sand and leaving the cover of the retort off, the coke will be dense and strong and without cells that are perceptible to the eye. On the other hand, coals, like the block coal of Indiana, which requires a very high temperature to melt its fixed carbon, does not have its coke expanded by heat induced by an over pressure of the eliminated gas, but as far as tried in the above experiments, the solidity of the block coal coke increased as the pressure was augmented by raising the column of mercury through which the gas had to escape; such coals, then, are eminently adapted, in the raw state, for smelting iron in the blast furnace. The closed top blast-furnace, with flues for conducting the waste gas produced by the combustion of the carbon and the distillation of the volatile hydrocarbons of the raw coal, presents similar conditions for the coking of the coal before it reaches the zone where it is ignited by the blast, to that given by the crucible tests without mercury pressure, but with a covering of sand. The latter materially increased the density of the coke and corresponds to the pressure that is exerted by the burden of the furnace. The blast furnace in which iron ores are smelted may be compared, in form, to two truncated cones joined at their bases; it is filled with alternate layers of fuel, ore and limestone. In the lower part or crucible of the great shaft a rapid combustion of the fuel is accomplished by means of a blast of heated air, which is sent in at the hearth with great force through a number of pipes called tuyeres. The heat thus produced fuses the inorganic substances and the iron, separated from the slag by its gravity, falls to the hearth at the bottom of the crucible and is finally run out into long bars called pigs. The chemical combination of the oxygen of the blast with the carbon of the ignited fuel, whether that be charcoal, coke or raw coal, forms, probably in the first instance, carbonic acid (C. O. 2.); but, investigation goes to show, that the permanent gas formed in this zone of the furnace is carbonic oxide, (C. O.) diluted with a large amount of nitrogen derived from the atmosphere. The gases thus formed ascend through the solid contents of the shaft to which they yield up a portion of their heat. In this way there are two currents established in the furnace, an upward current of heated gas which gradually parts with its heat as it ascends, and a descending current of solid minerals, which are cold when thrown in at the top, but become hotter and hotter in their descent until finally fused at the hearth. The carbonic oxide of the ascending current partly reduces the ore, which is in the condition of a peroxide of iron, by depriving it of a portion of its oxygen, so that before the gas leaves the top of the shaft a portion has been changed to carbonic acid. This deoxidizing of the ore, by carbonic oxide only, takes place under certain conditions and the amount of change is, at best limited. One of the most essential conditions to promote this action is the presence of moisture. The change thus made in the ore renders it porous and favors its final reduction. It is therefore an object of very great economical importance to obtain from the ascending gas all the chemical effect which it is capable of producing, both in the way of absorbing the oxygen from the ore and in heating the furnace before it is carried out of the top of the stack and further utilized in heating the boilers and blast-ovens. With a view to accomplish this end, very high furnaces have been built and the temperature of the blast air has been increased, and in both instances, within certain bounds, favorable results have been obtained.

INDIANA BLOCK COAL

is of itself very strong and able to bear up as much burden as coke, but it is, by the heat in the upper part of the furnace, converted into a dense coke before it meets the blast where it enters into perfect combustion. That my readers may comprehend the important part performed by the blast, I will state that more than five tons of air are required for every ton of pig iron smelted. From the fact that the raw coal is changed to coke before it is burned, the effect produced by the two fuels, coke and raw coal, are the same in the zone of fusion, and it is only in the upper part of the furnace that we must look for dissimilar effects. Here the raw coal is gradually heated and the hydrogen and hydrocarbons, which form about forty parts of its substance, are distilled off and the gaseous contents of the shaft are, consequently, about thirty-seven per cent greater than when coke is the fuel; it follows therefore that if the size of the throat and gas flues are properly adjusted for coke, they must be made, at least, one third larger for raw coal If this point is not attended to the furnace must lose heat, through want of perfect combustion, run irregular, and consume vastly more fuel per ton of pig iron made.

Mr. I. Lothian Bell, in his valuable work on the Chemical Phenomena of the blast furnace, says that "raw coal in the blast furnace requires the extra heat produced by fifteen pounds of coke, for every 100 pounds of coal, to expel the volatile matter, or in other words, to coke it, and its reducing powers are diminished consequently in that proportion." Mr. Bell arrives at this conclusion by ascertaining that fifteen pounds of coke are burned under the retorts, at the gas works, for expelling the gas from 100 pounds of coal, and he estimates the calories of coal and coke to be about the same. A similar showing is made if we reason from the process of making coke in ovens. Here the heat necessary for distillation is derived from the expelled gas, and of that one third only is required for the operation and the other two thirds are wasted for want of means to utilize it.

Under the most favorable management at Cleveland, in in the north of England, twenty two and one-half hundred weight of coke will smelt one ton of pig iron from Cleveland iron stone. This ore is a lean carbonate of iron, very similar in composition to the Clarke county, Ind., ore. Twenty two and five-tenths hundred weight, or 2520 pounds of coke will correspond to 3360 pounds ot block coal, and I have no doubt but that, when we have discovered the proper form of furnace and the best mode of preparing the stock at our command, less than two tons of block coal will be required to make a ton of pig iron.

The loss of heat by absorption, when raw coal is used in the blast furnace, is more than compensated for by the highly deoxidizing action of the hydrogen and hydrocarbons in which the ore is so comepletely bathed. The amount of oxygen absorbed from the ore by carbonic oxide, when the fuel is coke, reaches, under favorable conditions, about thirty per cent of the entire oxygen which it contains. Now, there is no reason why this reducing action of carbonic oxide should not proceed to completion if those aids which facilitate the reduction are present in sufficient quantity.

It has been proven by investigation that moisture must be present to promote this favorable action of carbonic oxide and, indeed, it is mentioned by some that the process of deoxidation cannot take place in the furnace without it. Raw coal supplies this essential constituent (H.O.), together with hydrogen (H.) in far greater abundance than coke; and since hydrogen is a much better deoxidizer than carbonic oxide, and the hydrocorbons themselves being almost as good absorbents for oxygen as the latter gas; I have every reason to believe that, when used under the most favorable conditions, we will obtain as large yields of iron with the Indiana block coal fuel as can be obtained from the same ores with coke, and the quality of the iron will be superior to that made with the latter fuel.

I am satisfied that most, if not all of the difficulties, experienced by the cooling and irregular working of the raw coal furnaces in this State, come from a want of sufficient sized outlet at the throat for the waste gases, for it must be borne in mind that the heat of the furnace, within certain bounds, depends upon a good upward draft.

HYDRAULIC CEMENT.

The manufacture of hydraulic cement constitutes one of the most important industries of Clarke county. No less than six mills are engaged in this branch of manufacture and the cement is shipped to all parts of the western and southern States and sold under the name of "Louisville Cement." The rock from which it is made is of the Devonian age and belongs to the corniferous epoch. It is in three layers and has a total thickness of fifteen to twenty-five feet. It crops out on both banks of the Ohio river at, and opposite, the ancient village of Clarksville, about two miles below Jeffersonville, and is exposed along the banks of Silver creek and its tributaries, to the northward, for a distance of fifteen miles or more. There are crops also in the neighborhood of Charlestown. The district which it occupies is included within the boundaries of the space numbered 4 on the map accompanying this volume.

The cement rock is again seen in Scott and Jennings counties, and will probably be found in Jackson, Decatur and other counties in this part of the State that have not yet been surveyed. It makes its appearance on the Wabash river in Wabash county, and near to the town of that name. At the latter locality it has been burnt and made into cement, and there are a number of cisterns in Wabash town that were lined with it, which have, so far as known, stood well and given good satisfaction. The analysis of the Wabash cement stone, collected from a bed ten to twelve feet thick, on the Davis farm near Somerset, Wabash county, has the following composition in one hundred parts of stone:

Moisture at 212° F	1.000
Silicic acid	30.600
Alumina	16.720
Carbonate of lime	25.600
Carbonate of magnesia	12.713
Carbonate of iron	2.480
Organic matter, alkalies undetermined and loss	10.887
	100.000

Another sample from a seam five to ten feet thick, on Helm creek, two miles west of Wabash town, contains:

Moisture at 212° F	2.000
Silicic acid	34.200
Carbonate of lime	28.000
Carbonate of magnesia	3.117
Carbonate of iron	1.242
Alumina	18.760
Loss and undetermined	12.681
	100.000

On Chapelle creek, LaGros, Wabash county, the seam is ten to fifteen feet thick, and contains:

Moisture at 212°F	1.80
Silicic acid	35.60
Alumina	17.86

Carbonate of lime	26.00
Carbonate of magnesia	2.42
Carbonate of iron	4.14
Loss and undetermined	12.18
	100.00

Judged by their composition these stones should make a good hydraulic cement.

It is well known that stone of very dissimilar composition, as regards the amount of lime, magnesia, silica and alumina which they contain, make equally good hydraulic cement.

Indeed by a proper admixture of argillaceous stone and sand with "fat" lime the very best quality of hydraulic cement may be made. Pure limestone, after being calcined, will absorb 22 to 23 per cent of water and passes into the condition of hydrate ot lime. The union is attended with great elevation of temperature and the lime breaks or is slaked into fine powder. On account of its affinity for water and carbonic acid, lime will absorb these substances from the atmosphere and gradually assume, under certain conditions, by returning to carbonate of lime, a stone-like hardness.

When lime is found mixed with impurities such as silica, alumina and magnesia, or when these are added to it in proper proportions it acquires the property of hardening under water, or when excluded from the air. Cements made in this way are used for the construction of masonry under water, building cisterns that are designed to hold water and for cementing all manner of mason work where the walls are exposed to dampness.

Hydraulic properties, or the property of hardening under water or in moist places, may be imparted, in a like perfect manner, to lime by admixing any of the above materials in proportions widely differing from each other. A knowledge of these facts, regarding the hardening of morter composed of an admixture of clay, lime, sand and gravel or fragments of stone, extends back to a period so remote that history can furnish no clue to its origin.

Common lime contains but a small amount of impurities, rarely as much as ten per cent; morter made of it alone will not harden under water, or in damp places if excluded from contact with the air. In the air it will dry and harden, but shrinks to such a degree that it cannot be used for building purposes without a large quantity of sand. Common morter used for building purposes is, therefore, composed of "fat" lime and sand.

Puzzuolana is the name of a hydraulic cement known to the Ancients and was employed in the marine constructions of the Romans. Puzzuolana derives its name from the village at the foot of Mt. Vesuvius where it was first discovered; it is is of volcanic origin and when mixed with sand and lime makes a durable hydraulic cement. Vitruvius gives the following formula, which is still very generally followed, for making this cement: *

Puzzuolana, well pulverized	12 parts.
Quartzose sand, well washed	6 parts.
Rich lime, recently slaked	9 parts.
Fragments of broken stone	6 parts.

It is not alone in Europe that we find a well founded claim of high antiquity for the art of making hard and durable stone by a mixture of clay, lime, sand and fragments of stone; for I am satisfied that this art was possessed by a race of people who inhabited this continent at a period so remote that neither tradition nor history can furnish any account of them. They belonged to the Neolithic or polished stone age. They lived in towns and built mounds for sepulture and worship, and protected their homes by surrounding them with walls of earth and stone. In some of these mounds specimens of various kinds of pottery, in a perfect state of preservation, have from time

* See Hydraulic Cement and Mortar's. Maj. Gen. Gillmore.

to time been found, and fragments are so common that every student of archæology can have a bountiful supply. Some of these fragments indicate vessels of very great size. At the Saline springs of Gallatin county, Illinois, I picked up fragments that indicated, by their curvature, vessels five to six feet in diameter, and it is probable that they are fragments of artificial stone pans used to hold brine that was manufactured into salt by solar evaporation.

Now, all the pottery belonging to the mound-builders, age, which I have seen, is composed of alluvial clay and sand or a mixture of the former with pulverized fresh-water shells. A paste made of such a mixture possess in a high degree the properties of hydraulic Puzzuolana and Portland cement, so that vessels formed of it hardened without being burnt as is customary with modern pottery. The fragments of shells served the purpose of gravel or fragments of stone as at present used in connection with hydraulic lime in the manufacture of artificial stone. It will be seen by the following analysis of a piece of ancient pottery from the "Bone Bank" in Posey county, Indiana, that, so far as chemical constituents are concerned, it agrees very well with the composition of hydraulic stones, and for the purpose of comparison I subjoin the analyses of natural Portland cement from Boulogne, France; artificial Portland cement from London; Rosedale cement stone from New York; Cumberland cement stone from Maryland and Balcony Falls cement stone from Virginia, copied from "A Practical Treatise on Coignet-Breton and other artificial Stone" by Maj. Gen. Q. A. Gillmore, pp. 12 and 13, and the Clarke county, Indiana, Hydraulic limestone, the analysis of which was made in my laboratory:

Ancient Pottery, "Bone Bank," Posey Co., Indiana:

Moisture at 212° F	1.00
Silica	36.00
Carbonate of lime	25.50
Carbonate of magnesia	3.20

Alumina	5.00
Peroxide of iron	5.50
Sulphuric acid	.20
Organic matter, alkalies and loss	23.60
	100.00

Boulogne Portland cement, (natural):

Lime	65.13
Magnesia	.58
Silica	20.42
Alumina and a small quantity of oxide of iron	13.87
Sulphate of lime	trace.

London Portland cement, (artificial):

Lime	68.11
Silica	20.67
Alumina	10.43
Oxide of iron	.87

Rosedale cement stone, (New York):

Carbonate of lime	46.00
Silica, clay and insoluble silicates	27.70
Carbonate of magnesia	17.76
Alumina	2.34
Peroxide of iron	1.26
Sulphuric acid	.26
Chlorides of potassium and sodium	4.02
Hygrometric water	.22
Loss	.44
	100.00

Cumberland cement stone, (Maryland):

Carbonate of lime	41.80
Silica, clay and insoluble silicates	24.74

Magnesia	4.10
Alumina	16.74
Peroxide of iron	6.30
Soda	4.64
Potash	1.54
Sulphuric acid	2.22
Hygrometric water	.60
	102.68

Balcony Falls stone, (Virginia):

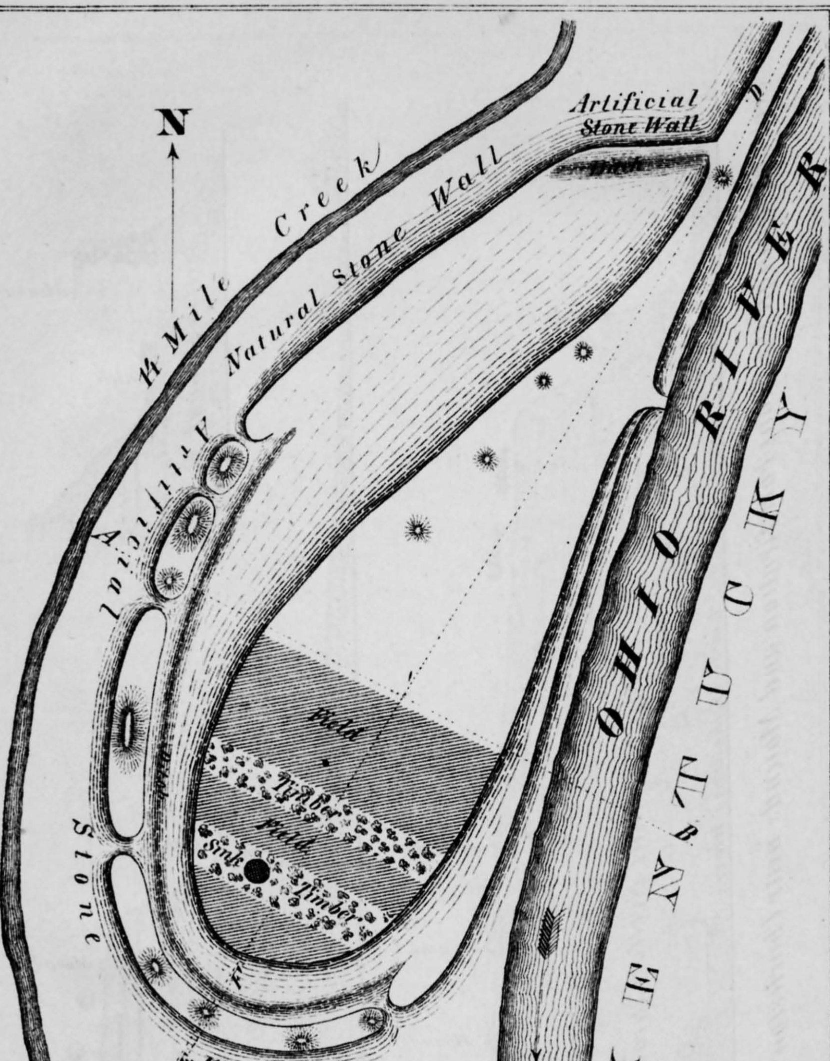
Lime	17.38
Silica	34.22
Alumina	7.80
Magnesia	9.51
Carbonic acid	30.40
Water and loss	.69
	100.00

Hydraulic limestone, Beach's Mill, Clarkesville, Clarke county, Indiana; color, ash gray; fracture, conchoidal; contains a few disseminated small crytals of iron pyrites.

Moisture at 212° F	.500
Loss by ignition, organic matter	5.000
Silicic acid, soluble	6.400
Silicic acid, insoluble	13.200
Carbonate of iron	2.548
Sulphate of iron	2.086
Carbonate of magnesia	2.631
Carbonate of potash	8.984
Carbonate of soda	3.676
Chloride of sodium	1.263
Alumina	14.573
Phosphoric acid	.195
Carbonate of lime	37.200
Loss	1.744
	100.000

In comparing the above analyses, one with another, it will be seen that the constituents of the so called Indian pottery, Rosedale, Cumberland, Balcony Falls, Clarke county and Wabash county cements are given from the stone which has not been calcined; whereas, those of the Portland cements are given from calcined stone. The only material difference is, that the latter contains a little more lime than the American cements and will therefore admit of a larger proportion of sand or gravel, in producing from it either hydraulic mortar or artificial stone. Notwithstanding the high antiquity of the art of manufacturing artificial stone from an admixture of calcareous, siliceous and aluminous earths, there remains, still, much to be learned before such stone can be looked upon with much favor for ordinary flagging and building stone. I am well aware that concrete is extensively used for the embellishment of some of the finest and most costly of modern buildings, both in Great Britain and on the Continent, but in many cases it was wearing badly, and at best presented but a scaly appearance by the side of ordinary natural stone.

Artificial stone formed a conspicuous feature among the other industries exhibited at the Vienna Universal Exposition. It was formed into statues, vases, building blocks, flag stones ornamented with figures formed by embedded fragments of colored stones; tile for paving courts, halls etc. The great steps, in the hotels, are made of concrete and on every story the halls are laid with it. Fine brick buildings are adorned, on the outside, with a coating of concrete, which formed a cheap imitation of stone; but do what they would the sham was prominently apparent and the walls require patching, annually, to keep up a respectable appearance. During the holding of the Exposition there was so much building going on in Vienna, and the use of concrete, made of Portland cement mixed with sand, was carried to such a pitch, that the atmosphere was loaded with the peculiar oder of mortar, due, no doubt, in part to the elimination of ammonia from the clay. Drain tile and large pipes for sewers, similar to those manufactured by the



MAP OF A
STONE FORTIFICATION AND MOUNDS
on the Ohio River 3 Miles East of Charlestown, Clarke Co., Indiana.

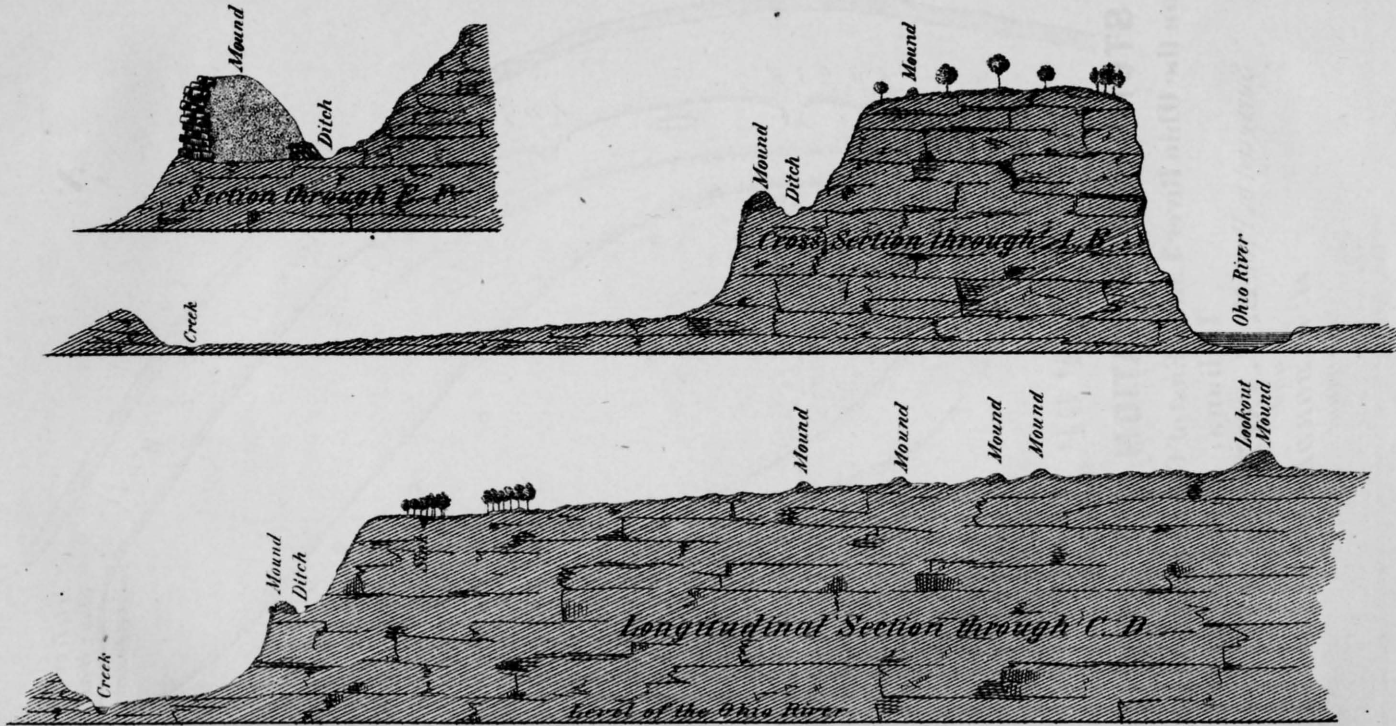
Surveyed by Prof. **E. T. COX**, *State Geologist*

and

W. W. BORDEN,

Assistant.

Braden & Burford, Steam Lith, Indianapolis.



Sections through the Stone Fortification and Mounds near Charlestown, Clarke Co, Indiana.

Bradley & Burford, Steam Lith, Ind^s

Indianapolis Pipe Manufacturing Co., and made of cement, were also on exhibition, but I saw no large pipes that were as smooth and free from cracks as those made in this city. The climate of Europe appears to be less trying on the durability of artificial stone than that of America, and to this may be added a possible better knowledge of the art of manufacturing; these may be the reasons for its general good favor there and discredit here.

I do not, however, wish to be understood as endeavoring, by the above remarks, to disparage the entire use of artificial stone, but rather as pointing out its present defects to encourage the use ot a better article which, I am sure, from the nature of the chemical reaction which takes place between the component parts, can be made when a more perfect knowledge of the subject is acquired; nor can I see why the Portland cement should have preference over that made in Clarke county and sold in the market under the name of "Louisville Cement."

It would be advisable, if the proper apparatus can be furnished by the State, to institute a series of experiments for determining the hardness and strength of stone or hardened mortar made of the various hydraulic stones which occur in such abundance in Indiana, and from which a large annual revenue is derived. These investigations, if properly managed, will furnish a vast amount of useful information in regard to the selection of the stone and its subsequent treatment to insure uniform results and a superior article of cement. Such an apparatus will also serve for testing the strength of stone, its resistance to a crushing force, the tensile strength of iron, etc., etc.

MOUNDS AND MOUND BUILDERS' IMPLEMENTS.

No departmeut of natural history appears, at this time, to attract more general interest than that which ralates to pre-historic man; nor is this to be wondered at, for, go where you will in the extensive valley of the Mississippi and other portions of the United States, south of the great lakes, you will meet with numerous mounds and earth and stone wall enclosures. Many of these mounds vie with the pyramids of Egypt in magnitude and, when taken in connection with the walls of earth and stone which have been thrown up to enclose large areas of country, bear evidence of a powerful nation, which in numbers may have equalled, if they did not excel, the present population of the Mississippi valley.

No written history or puzzling hieroglyphics have been left behind, nor could any reliable account be obtained from the savage races who were found in posesession of the country by the earliest white explorers, that could give any clue to the antiquity of these mounds and walled enclosures. To them, all was as inexplicable as to us. They found growing on the mounds large forest trees, and the earth-works presented then, as now, evidence of decay and great age.

The tumuli and walled enclosures of this pre-historic people whom we call mound builders for want of knowledge of their true natural name, are found in the greatest numbers situated mostly on the first and second river terraces and seldom, on the low bottom land along the large rivers and their principal tributaries. This has led many to infer that the rivers have since the time of the mound builders, narrowed and changed their channels, within an area equal to the width of the present alluvial bottoms.

The extent and magnitude of the works executed by these people, lead to the inference that they lived in towns and were governed by a despotic ruler whose will was law and whose commands received implicit obedience.

Their food consisted principally of the flesh of all kinds of animals, as may be seen by the bones which are found in the refuse piles from their kitchens.

Fresh water bivalves (Unionidæ) and univalve mollusks were also consumed in such quantities that great banks of shells, miles in length, are left to mark the places where, it is possible high carnivals were held over fresh water "Clam-bakes."

At Clarksville, just below the falls of the Ohio river, in

Clarke county, there is a shell heap extending for a mile or more up and down the river. This locality must have been a favorite place of resort; an ancient Long Branch where it was possible to find enjoyment and pass a pleasant summer catching fish at the foot of the falls, where they congregated at certain seasons of the year in such vast numbers as to become an easy prey to the bone-hooks and spears used for their capture by these pre-historic people.

In digging a foundation on the bank of the river for a new calcining kiln at Mr. H. Beach & Co.'s cement mill the excavation went through a shell heap in which Mr. Beach found a number of stone relics; a large greenstone axe highly finished; an oval shaped stone sixteen inches long, three inches in diameter in the middle and one and a half inches at each end. One of the ends is worn to a smooth conical point. It is made of corniferous limestone. A fragment of a similar instrument, broken in the middle where it is six inches in diameter was never finished, probably on account of its accidental breaking. The hammer marks produced by working it in to shape are still plainly to be seen. Along with the above instruments of stone was an awl made of a fragment of deer's bone. The shell heaps of this region have furnished to the explorers from time to time, a large number of bone fish hooks, knives, awls and other ornaments of bone, many of which are preserved in the cabinet of the New Albany Historical Society. I may add also that this society has one of the largest and most interesting archæological collections in the State.

At the mouth of Fourteen Mile Creek, and about three miles from Charlestown, the county seat of Clarke county, there is one of the most remarkable stone fortifications which has ever come under my notice. Accompanied by my assistant, Mr. Borden, and a number of citizens of Charlestown, I visited the "stone fort," as it is called, for the purpose of making an examination of it. The accompanying map, page 123, made by stepping over the ground will serve to give a general idea of the extent and character of the work.

The locality selected for this fort presents many natural advantages for making it impregnable to the opposing forces of pre-historic times. It occupies the point of an elevated narrow ridge which faces the Ohio river on the east, and is bordered by Fourteen Mile Creek on the west side. This creek empties into the Ohio a short distance below the fort. The top of the ridge is pear shape, with the part answering to the neck at the north end. This part is not over twenty feet wide and is protected by precipitous natural walls of stone. It is two hundred and eighty feet above the level of the Ohio, and the slope is very gradual to the south. At the upper field it is two hundred and forty feet high and one hundred steps wide. At the lower timber it is one hundred and twenty feet high. The bottom land at the foot of the south end is sixty feet above the river. Along the greater part of the Ohio river front, there is an abrupt escarpment of rock entirely too steep to be scaled, and a similar natural barrier exists along a portion of the north west side of the ridge facing the creek. This natural wall is joined to the neck by an artificial wall made by piling up, mason fashion, but without mortar, loose stone, which had evidently been pried up from the corniferous layers at the point marked D. This made wall at this point is about one hundred and fifty feet long. It is built along the slope of the hill and had an elevation of about seventy-five feet above its base, the upper ten feet being vertical. The inside of the wall is protected by a ditch. The remainder of the hill is protected by an artificial stone wall built in the same manner but not more than ten feet high. The elevation of the side wall above the creek bottom is eighty feet. Within the artificial walls are a string of mounds which rise to the height of the wall and are protected from the washing from the hill sides by a ditch twenty feet wide and four feet deep. The position of the artificial walls, natural cliffs of bedded stone, as well as that of the ditch and mounds will be better understood by a reference to the accompanying map and cross sections. The top of the enclosed ridge embraces ten or twelve acres, and there are as many as five mounds that can be recognized on the flat surface, while no doubt many others existed which have been obliterated by time and through the agency of man in his efforts to cultivate a portion of the ground. The section through E F shows the relation of the stone wall to the mounds on the south end of the ridge. A trench was cut into one of these mounds in search of relics. A few fragments of charcoal and decomposed bones and a large, irregular diamond-shaped boulder, with a small circular indentation near the middle of the upper part that was worn quite smooth by the use to which it was put, and the small pieces of fossil coral—*favosites goldfussi*—comprised all the articles of note which were revealed by the excavation. The earth of which the mound is made, resembles that seen on the side of the hill and was, probably, in most part taken from the ditch. The margin next to the ditch was protected by slabs of stone set on edge and leaning at an angle corresponding to the slope of the mound. This stone shield was two and a half feet wide and one foot high. At intervals along the great ditch there are channels formed between the mounds that probably served to carry off surplus water through openings in the outer wall.

On the top of the enclosed ridge, and near to the narrowest part, there is one mound much larger than any of the others and so situated as to command an extensive view up and down the Ohio river, as well as affording an unobstructed view east and west. It is designated on the sketch as "Lookout Mound."

There is, near this mound, a slight break in the cliff of rock which furnished a narrow passage way to the Ohio river.

Though the locality afforded many natural advantages for a fort or stronghold, one is compelled to admit that much skill was displayed and labor expended in rendering its defense as perfect as possible at all points. Stone axes, pestles, arrow heads, spear points, *totums*, charms and flint flakes have been found in great abundance in plowing the field at the foot of the old fort.

While calling attention to the remarkable works of the Mound builders in Clarke county, I desire also to say a few words about another very remarkable locality situated on the Wabash river, about ten miles above its mouth, in Posey county. It is called the "Bone Bank" on account of the many skulls and other human bones which have been washed out on the bank of the river and elicited the attention of navigators from the earliest settlement of the country to the present time.

Dr. G. M. Levette visited the "Bone Bank" last November and made the map which accompanies this report. (See frontispiece). It is situated in a bend on the left bank of the river, and the ground is about ten feet above high water mark, being the only land for many miles along this part of the river that is not submerged in seasons of high water. The bank slopes gradually back from the river to a slough. This slough now seldom contains water, but no doubt, at one time, it was an arm of the Wabash river, which flowed around the "Bone Bank" and afforded protection to the island home of the Mound builders. It will be seen, by reference to the map, that the Wabash has been changing its bed for many years, leaving a broad extent of newly made land on the right shore and gradually making inroads on the left shore by cutting away the "Bone Bank." The stages of growth of land on the right bank of the river are well defined by the cotton wood trees which increase in size as you go back from the river.

Unless there is a change in the current of the river, all trace of the "Bone Bank" will be obliterated. Already, within the memory of the white inhabitants, the bank has been removed to a width of several hundred yards. As the bank is cut by the current of the river it loses its support, and when the water sinks it tumbles over, carrying with it the bones of the Mound builders and the cherished articles buried with them. No locality in the country furnishes a greater number and variety of relics than this. It has proved especially rich in pottery of quaint design and skillful workmanship. I have a number of jugs and pots and a cup found at the "Bone Bank," all of which will be figured in a future report. This character of ware has been very abundant and is still found in such quantities that we are led to conclude that its manufacture formed a leading industry of the inhabitants of the "Bone Bank."

I have already, on page 119 of this report, called attention to the composition of the pottery found at the "Bone Bank," and put forth the opinion, based upon the result of its analysis, that it is simply an artificial stone made from a mixture of river mud and pulverized fresh water shells. Instead of softening in water, as they would if made of clay alone, the shells give to the composition hydraulic properties, and vessels made of it harden on exposure to air and moisture. When filled with water and meat, pots made of this material could be placed over the fire and heated without fear of breaking them. Those ancient artizans must have been aware of the advantage derived from a thin body to resist breakage from expansion and contraction from the heat of the fire. I have a beautiful vessel, from the "Bone Bank," made of artificial stone, which has ears, and is otherwise formed, like an old fashioned cast iron dinner pot. It is five inches across the mouth and seven inches in diameter at the bulge, five inches deep and only one-eighth of an inch thick. The bottom is smoked black, which goes to show that it was suspended over the fire for cooking purposes.

The following memoranda were made by Dr. Levette at the time of his visit:

"The 'Bone Bank' forms the east bank of the Wabash river for fifteen hundred feet, is one hundred and eighty feet wide at the widest point near the south end, and thirty-five feet above the water at the highest point;* it is situated in sections 7 and 18, town 8 south, range 14 west,

*At the time of my visit, 15th of November, 1873, the river was very low.

in Posey county, Indiana; two and a half miles due north of the confluence of the Wabash with the Ohio river, and ten miles by the tortuous current of the first named stream."

"Within the memory of the early settlers the 'Bank' was two or three times its present width; but the current of the river, during each freshet, impinges violently on the exposed front, and will, in time, carry the last vestige of it into the river."

"Though no mounds are now visible on the top of the 'Bank,' the old settlers distinctly remember some small hillocks, or tumuli, on the southern and higher end; whether these were mounds of sepulture, sacrifice, or observation, can not now be determined. The whole surface is strewn with countless fragments of pottery, broken during the process of manufacture, or by subsequent use. There is a dwelling house on the south end, the residence of Joseph Reeves, Esq., the owner of a tract of land of which the 'Bank' is a part. He informed me that almost every post-hole, or other slight excavation made, exposed human bones and pottery."

"Formerly the 'Bank' was sparsely covered with gigantic forest trees, larger than those in the adjoining forest; but never, within the memory of white men, so densely covered with trees as the adjacent lower lands."

"The opinion held by some archæologists, that the 'Bone Bank' is a true mound, constructed of earth taken from the slough on the east side of it, can not be sustained in the face of the fact that the strata of coarse and fine sand and gravel of various shades of color, may be distinctly traced from the water's edge to within two feet of the top of the 'Bank' at its highest point, and for the whole length of it up and down the river."

ANALYSES OF IRON ORES.

County.	Name of Locality or Owner.	Water Dried at 212°.	Combined Water and Organic Matter.	Silicic Acid.	Per Oxide of Iron.	Prot Oxide of Iron.	Metallic Iron.	Prot Oxide of Manganese.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.	Carbonic Acid.	Undetermined and Loss.
Clarke......	Near Henryville, lower band....................	.50	....	14.30	....	35.98	28.00	7.44	1.50	6.82	3.20	.055	.559	....	29.646
Clarke........	Near Henryville, bottom band, No. 10.......	....	....	7.30	2.128	34.70	28.48	8.94	1.10	5.824	3.027	.254	.321	29.50	6.906
Clarke........	Near Henryville, Stewart's, No. 5............	.50	4.575	9.30	2.042	35.60	29.12	6.628	3.60	7.168	4.612	.274	.340	24.925	.436
Clarke........	Medzker's..	.50	22.50	16.00	....	40.00	31.11	8.00	2.50	18.00	13.20	2.10	.860	....	....
Lawrence ...	Geo. Whitaker...	....	13.00	1.20	....	83.20	64.71	none	trace	2.00	none	trace	.064	....	....
Lawrence ...	From Shoals Furnace Co..........................	....	13.00	.90	....	84.89	66.02	none	trace	1.00	none	....	.0449	....	....
Crawford.....	C. C. Taylor, near Marengo.....................	....	33.00	6.10	5.10	33.92	30.05	3.95	2.00	6.80	7.30	.104	.221	....	....
....	Caldwell & Co., near Elizabeth, Ky..........	....	5.50	29.00	....	64.00	49.78	.70	.618	8.00	....	trace	.102	....	....
Warren	Cedar Bluff, No. 1....................................	....	....	10.10	....	47.86	37.22	.718	2.49	3.33	.218	....	....	....	35.282
Warren	Cedar Bluff, No. 2....................................	....	....	11.70	....	48 08	37.40	.837	1.89	4.48	.232	....	....	....	32.785
....	St. Bernard, Ky., (Black Band ?).............	....	12.10	15.40	....	31.89	24.80	2.99	1.38	32.50	2.64	1.10	....	....	....
....	Red Mountain, Tenn................................	....	....	23.20	....	66.00	51.33	trace	6.00	3.20	1.60	....	....	....	....
Sullivan......	Ferruginous Sand Stone, near Sullivan......	....	....	53.00	....	34.28	26.66	....	4.52	....	....	....	....	....	8.20
Posey	Pottery, from "Bone Bank.".....................	1.00	23.60	36.00	....	5.50	....	....	5.00	25.50	3.20	.20	....	....	....

ANALYSES OF LIMESTONE AND HYDRAULIC CEMENT ROCKS.

County.	Name of Locality or Owner.	Moisture at 212°.	Insoluble Silicates.	Oxide of Iron.	Alumina.	Carb. of Lime.	Carb. of Magnesia.	Organic Matter, Alkalies, &c.	Sulphuric Acid.	Carb. of Iron.
Wabash	Davis Farm, near Somerset	1.00	30.60	....	16.72	25.60	12.713	10.887	....	2.48
Wabash	Helm Cr., near Wabash	2.00	34.20	....	18.76	28.00	3.117	12.681	....	1.242
Wabash	Chapelle, Cr., near LaGros	1.80	35.60	....	17.86	26.00	2.420	12.180	....	4.140
Clarke	Beach's Mill, Clarksville	0.50	19.60	....	14.57	37.00	2.631	20 862	....	4.634
Clarke	W. F. Beach & Co., Falls of the Ohio, middle	1.00	14.00	....	10.80	38.00	4.708	29.835	....	1.657
Clarke	W. F. Beach & Co., Falls of the Ohio, bottom	1.30	15.40	....	19.60	37.00	2.332	23.540	....	.828
Clarke	W. F. Beach & Co., Falls of the Ohio, top	0.50	15.50	....	3.50	53.80	11.348	14.873	.48	....
Cass	Near Logansport, Limestone	0.80	2.20	1.50	5.30	79.60	1.200	9.400	....	....
Miami	Wallack's Mill, near Peru, Limestone	1.20	6.40	....	14.343	45.00	23.610	7.790	....	1.657